

Eng. Div. - 1000

EASTPORT HARBOR

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MAINE

GENERAL DESIGN MEMORANDUM FOR CONSTRUCTION OF A BREAKWATER



U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

MARCH 1961

407-423

ENGW-E (20 Mar 61) 1st Ind
SUBJECT: /General Design Memorandum for Construction of a Break-
water at Eastport Harbor, Maine/

Office, Chief of Engineers, Washington 25, D.C., 14 April 1961

TO: Division Engineer, U.S. Army Engineer Division, New England
Waltham, Massachusetts

The General Design Memorandum for construction of a breakwater at Eastport Harbor, Maine is approved subject to the following comments:

a. The sheet piling walls should be designed assuming that the piling is hinged about .10 H below the ground or dredge line, instead of fixed at the ground line. In the breakwater section, where the piling would be assumed fixed about 5 ft. below the ground, a preliminary analysis indicates that Z-38 piles are needed. Channel wales and tie bars would be revised as necessary. The two sheet-pile walls tied together in this section are less flexible than independent walls, and assuming the hinge point higher than usual is considered especially unconservative.

b. It is suggested that walers and tie bars be designed for 16,000 psi working stress because of exposure to salt water. It is suggested that the upper tie bars in the breakwater section be increased somewhat over the theoretical size to allow for racking.

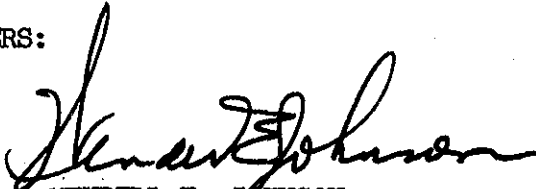
c. Material for sheet piling should conform to the inclosed CE-1304.01, Amend. 2, April 1961.

d. The bituminous cap on the steel sheet pile structures should be increased to 4 inches applied in 2 layers.

e. Coal tar paint is not considered appropriate for these conditions. A 7-mil thickness of vinyl paint should be used.

FOR THE ACTING CHIEF OF ENGINEERS:

1 Incl
Guide Specs for
Piling; Steel Sheet


WENDELL E. JOHNSON
Chief, Engineering Division
Civil Works

Engrg Div Ref File

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND

CORPS OF ENGINEERS

424 TRAPELO ROAD
WALTHAM 54, MASS.

DRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDGW

20 March 1961

SUBJECT: General Design Memorandum for Construction of a Break-
water at Eastport Harbor, Maine

TO: Chief of Engineers
Department of the Army
Washington, D. C.
ATTN: ENGCW-E

Submitted herewith in accordance with EM 1110-2-1150 are 10
copies of design memorandum for review and approval.

1 Incl
Design Memorandum
(10 cys)

KARL F. EKLUND
Colonel, Corps of Engineers
Deputy Division Engineer

cc: Mr. Leslie 11
Mr. Dingwall 12
Mr. Fogarty 13
Mr. Groden 14
Mr. Linnell 15
~~Mrs. Thompson (for only)~~
Operations Div 16
Engrg Div Ref File 17

GENERAL DESIGN MEMORANDUM
FOR
CONSTRUCTION OF A BREAKWATER
AT
EASTPORT HARBOR, MAINE

PERTINENT DATA

Authorizing Act: River and Harbor Act approved 14 July 1960.

Project Document: Senate Document No. 98, 86th Congress, 2nd Session.

Date of Report of Chief of Engineers: 6 May 1960

Description of Federal Improvement: Eastport Harbor on the east side of Moose Island, Maine is on Friar Roads, an international boundary passage between Moose Island and Campobello Island, New Brunswick. Eastport, the most easterly city in the United States, occupies the whole of Moose Island and is important as one of the major centers of the nation's sardine canning industry and as a summer colony. The authorized project contained herein provides for the construction of a breakwater approximately 500 feet long generally parallel to the central waterfront and an anchorage basin of 1.4 acres behind the breakwater with depths of 10 and 14 feet.

Principal Items of Work:

Federal Project

Breakwater. - Construction of 490 linear feet of double row steel sheet piling, stiffened with steel channel wales and tied together with steel tie rods. The inside of the breakwater will be filled with quarry-run stone topped with gravel base and 2-inch cold-mix bituminous gravel paving.

Excavation. - Dredging 20,000 cubic yards place measurement.

Non-Federal Project:

Public Landing. - Construction of a stone approach 100 feet long with a top width of 35 feet and a steel faced pier 140 feet long and 40 feet wide connected to the Federal Breakwater. The stone approach will be constructed with quarry-run stone and the steel faced pier

constructed with a double row of steel sheet piling, stiffened with steel channel wales and tied together with steel tie rods. The inside of the steel faced pier will be filled with quarry-run stone and both the stone approach and steel faced pier will be topped with a gravel base and 2-inch cold-mix bituminous gravel paving.

Construction of a timber fender system along each face of the steel faced pier and Federal Breakwater.

Excavation. - Dredging 5,000 cubic yards place measurement.

Estimated Cost of Project. - Based on current 1 January 1961 price levels.

	<u>Federal</u>	<u>Non-Federal</u>	<u>Total</u>
Construction of Breakwater and excavation	\$605,000		\$605,000
Aids to Navigation	0		0
Construction of Public Landing, berth excavation, and furnishing and installing fish pump	0	(*) \$150,000	150,000
Total	\$605,000	\$150,000	\$755,000

(*) These costs are considered to be self-liquidating. The city of Eastport requested that the Corps of Engineers accept a contribution of funds in an initial amount of \$150,000 from the city of Eastport to design and construct the features included under this item. This request was approved by the Secretary of the Army on 8 February 1961. The city of Eastport will withhold \$2,500 from the initial amount whereby they will purchase and install the fish pump after the construction work has been completed.

Estimated Time Required for Completion of Federal and Non-Federal Project Work:

Approximately 5 months.

Federal Funds Allotted to Project to Date:

Allotments to date - \$310,000

Additional Federal Funds Required to Complete:

Required in F.Y. 1962 - \$295,000

Non-Federal Funds Allotted for Public Landing & Berths:

Allotments to date - \$3,000

Additional Non-Federal Funds Required to Complete:

Required prior to advertizing this work \$144,500*

*Exclusive of \$2,500, cost of fish pump to be installed by local interests.

Benefit-Cost Ratio:

2.5 to 1

GENERAL DESIGN MEMORANDUM
FOR
CONSTRUCTION FOR A BREAKWATER
EASTPORT HARBOR, MAINE

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<u>Number</u>	
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2	Project Plan & Subsurface Explorations
3	Sections & Details
4	Wind and Wave Exposure Diagram

EXHIBITS

<u>Exhibit</u>	
A	Structural Design Computations
B	Wave Study for Breakwater Design

GENERAL DESIGN MEMORANDUM
FOR
CONSTRUCTION OF A BREAKWATER
AT
EASTPORT HARBOR, MAINE

AUTHORIZATION

1. The Federal navigation project considered herein is authorized by the River and Harbor Act of 14 July 1960 in accordance with the plans recommended in Senate Document No. 98, 86th Congress, 2d Session.

2. The project provides for construction of a cellular steel sheet pile breakwater approximately 500 feet long parallel to the central waterfront, and an anchorage basin of 1.4 acres behind the breakwater with depths of 10 and 14 feet. The segmental cells are to be filled, for stability, with sand and gravel secured from local sources. Dredging will be required to provide the anchorage area in back of the breakwater. The primary purpose of the breakwater and anchorage is to provide a protected landing area so that fish and general cargo could be landed during periods of rough weather and to provide a protected anchorage area for fishing and other craft.

3. The improvement, authorized by the act of 14 July 1960, is subject to the conditions that local interests:

a. Furnish without cost to the United States all lands, easements, and rights-of-way for the construction and maintenance of the project, when and as required;

b. Hold and save the United States free from damages due to the construction and maintenance of the project; and

c. Provide and maintain without cost to the United States an adequate public landing joining the breakwater to shore, with a fish pump or other acceptable unloading device, berths, and necessary mooring facilities, open to all on equal terms.

INVESTIGATIONS

4. Project Document. - Investigations made in connection with preparation of the survey report printed in Senate Document No. 98 consisted of a detailed hydrographic survey including soundings and probings of the waterfront area. Commercial statistics and other data pertaining to the harbor were examined.

5. Prior to Project Document. - The hydrographic survey of the entire Eastport waterfront made in relation to an unfavorable survey report submitted in 1939 was studied.

6. Subsequent to Project Document. - A topographic and sounding survey at the shoreward end of the public landing was made in December 1960. Eight borings were made in November and December 1960. The detailed hydrographic survey showing soundings and probings of the waterfront area made in 1957 in connection with the preparation of the survey report, and the more recent surveys and borings are considered sufficient for design needs for the project considered herein. The results of the surveys and the locations and logs of the borings are shown on Plates 2 and 3 herewith.

7. A wave study analysis was made to determine structural design criteria. A report of the results of the wave study analysis is included as Exhibit B accompanying this design memorandum.

8. Although no public hearings have been held subsequent to the hearing in connection with the survey report, close contact has been kept with responsible local agencies throughout the preparation of this design memorandum.

LOCAL COOPERATION REQUIRED AND VIEWS OF LOCAL INTERESTS

9. Local cooperation required by the authorizing legislation is set forth in Paragraph 3 of this memorandum.

10. The present status of actual compliance with the requirements of local cooperation is as follows:

a. The city of Eastport has a Warranty Deed proving ownership of land upon which the Public Landing is to be constructed. There are no land acquisition problems involved for the construction and maintenance of the off-shore Federal Breakwater and Anchorages since their locations lie seaward of the low water line. The city of Eastport will furnish all easements and rights-of-way when required. There will be no spoil disposal areas required on shore.

b. The Governor of the State of Maine is ready to sign the assurance to hold and save the United States free from damages due to the construction and maintenance of the project as soon as the State Legislature approves State funds for construction of the Public Landing. Allocation of State funds in the amount of \$150,000 was taken under advisement by the Committee on Appropriations of the Maine Legislature after a hearing held in Augusta on 21 February 1961. The city of Eastport has furnished the necessary assurances properly executed by city officials.

c. No public landing or facilities have been constructed. The city of Eastport formally requested by letter dated 18 January 1961 that the Corps of Engineers accept a contribution of funds from the city of Eastport to design and construct a public landing joining the breakwater to shore, berths and necessary mooring facilities. The formal request from the city of Eastport was approved by the Secretary of the Army on 8 February 1961.

d. The design of the Public Landing is included in this memorandum. Local interests will furnish and install a fish pump or other acceptable unloading device after the construction of the breakwater and public landing are completed. The estimated cost of the Public Landing including the fish pump as stated in the authorizing document is \$150,000.

LOCATION OF PROJECT AND TRIBUTARY AREA

11. Eastport Harbor, on the east side of Moose Island, Maine, is on Friar Roads, an international boundary passage between Moose Island and Campobello Island, New Brunswick. The harbor is an open waterfront about 3 miles north of Lubec, and 40 miles northeast of Machias, Maine. The city of Eastport is important as one of the major centers of the nation's sardine canning industry, and as a summer colony. The manufacture of extracts from fish scales and scrap is also one of the city's major industries. In 1955 the permanent population of the city was about 3,200 and the assessed real estate evaluation was about \$1,699,000. Insofar as the fishing industry is concerned, the tributary area includes the surrounding islands in both Canada and the United States.

PROJECT PLAN

12. The plan considered the most feasible for carrying out the authorized project is in general accordance with plans outlined in Senate Document No. 98 except for modification described in paragraphs 13 and 14 of this memorandum. The plan provides for a breakwater parallel to the central waterfront with its north end turned at right angles toward shore, and an anchorage basin of 1.4 acres behind the breakwater with depths of 10 and 14 feet.

DEPARTURES FROM PROJECT DOCUMENT PLAN

13. Subsequent to the studies made for the Project Document Plan, a conference on Harbor Design was held at the office of the Chief of Engineers in December 1960. At this conference, maximum allowable wave heights in harbors were discussed and it was pointed out that wave heights of 0.5 to 1 foot on the west coast and 2 feet in the Great Lakes were troublesome in small boat harbors.

Since the primary purpose of the breakwater and anchorage is to provide a protected landing area and anchorage for fishing and other smaller craft, the necessity to prevent waves of 0.5 to 2 feet from occurring within the anchorage area is of vast importance. It is, therefore, considered that instead of extending the north end of the breakwater in a straight line approximately 50 feet beyond its intersection with the Public Landing as outlined in the Project Document, the breakwater would serve more effectively by turning this end toward shore to afford more protection to the anchorage areas from northeasterly storms. Local interests were consulted and they agreed to the proposed change in alignment at the north end of the breakwater. They were more favorable to the present proposed layout than the Project Document Plan on the grounds that since the most troublesome storms are from the northeast, the additional protection to the anchorage areas from these storms is needed.

14. The type of breakwater has been changed from a cellular steel sheet pile construction filled with sand and gravel, to a double row of steel sheet piling, fastened with steel channel wales and tie rods and filled with quarry-run stone. The double row of steel sheet piling type of breakwater was considered more suitable and less expensive than the cellular steel sheet pile type and does not rely on interlock strength. Its suitability is based on the following:

a. The range in tide of over 18 feet permits placing wales and tie rods at the required locations to stiffen and hold the walls without the use of divers and under-water equipment.

b. Since the breakwater is also to serve as a landing for fishing and other craft, the design of an adequate fender system is greatly simplified. The first cost and maintenance repair cost of the fender system, both of which must be borne by local interests, is considerably less.

15. A meeting was held on 18 January 1961 with representatives of the Canadian Department of Public Works, Harbours and Rivers Engineering Branch, Saint John, New Brunswick, Canada. The purpose of the meeting was to obtain information regarding the design and durability of harbor structures that the Canadian government has built in northern waters under somewhat similar exposures as the Eastport Breakwater. It was found that their common practice, for the past 40 years, has been to build piers and minor breakwaters with parallel lines of steel sheet piling connected with wales and tie-rod systems and filled with suitable, available granular material.

16. Such structures have been erected along the St. Lawrence River where the ice conditions, as well as waves, are a major factor; along the Northumberland Straits, where wave and sand abrasion are major factors; and along the Atlantic seaboard, where ocean waves become the major problem. Some of these structures have been in use for 30 to 40 years and it was stated that they still appear to be in good usable condition.

17. As an example of a structure that would be near Eastport, Maine, they furnished plans of a breakwater-landing that had been built in 1956 at Ingall's Head, Grand Manan Island, which is off the coast about 20 miles southeast of Eastport. This breakwater-landing was built of parallel walls of steel sheet piling connected with rods and wales and filled with gravel and was connected to the shore with a rock-dike roadway. While this structure did not have as much depth as the Eastport breakwater, it was exposed to winds from the open sea on its south side and, thus, was subject to greater wave action. It was understood that this breakwater has withstood hurricane winds and proved entirely adequate.

18. In regard to protection of the sheet piling from corrosion, it was stated that they had found no satisfactory method. All they are doing is to coat the piling with a coal-tar paint mainly for the sake of appearance although they believed that this would increase the life of the material by at least 5 years.

19. A thorough study has been made by them of the rate of corrosion of their structures and they found a range from nearly zero to .008 inches per year, with this high rate due to sand abrasion in the Prince Edward Island area. For design purposes in locations similar to Eastport, they use a rate of .0025 inches per year or about 1/16 inch in 25 years.

WEATHER CONDITIONS

20. In connection with the wave study analysis (Exhibit B) studies were made of both weather and maximum high tide records. Frequency of wave heights from various directions at Eastport were computed based on the length of fetch and a wind velocity of 50 miles an hour. Records of wind consisted of those at Portland, Maine, located about 185 miles southwest of Eastport, the nearest locality with such records. It was found that the maximum deep water wave heights could be developed over the maximum fetch distance extending from the breakwater site in a northeast direction. It was found that the maximum waves acting on the breakwater would be from winds acting over the longest fetch of 10 miles from the northeast through Head Harbour Passage.

21. For structural design purposes a wind velocity of 50 miles per hour was assumed resulting in a significant wave $H(1/3)$ of 7.0 feet. The breakwater and steel faced pier are designed to withstand a maximum wave of 1.58 x 7.0 feet or 11.1 feet. It is recognized that this figure may be conservative and also that an additional factor of safety is provided, since these waves do not strike the breakwater at right angles but at an oblique angle. The Design Wave for harbor structures was discussed at the conference on Harbor Design held at the office of the Chief of Engineers in December 1960, and it was brought out that European practice is to reduce wave stress due to angular approach. However, due to lack of knowledge in computing this reduction, the direction of wave approach has been disregarded in establishing the design wave for the harbor structures at Eastport.

22. The mean tidal range at Eastport is 18.2 feet and the spring range is 20.7 feet. Based on tidal measurements by the United States Coast and Geodetic Survey during a continuous period from 1929 through 1957, the extreme recorded tides were 23.2 feet (November 1945) above mean low water and 4.2 feet (January 1943) below mean low water. The design still water level has been taken as 23 feet above mean low water to determine wave loading for the harbor structures.

SUB-SURFACE CONDITIONS

23. The soil investigation for the construction of the Federal Breakwater and the Public Landing and the required dredging in the anchorage were made in November and December 1960. The location and logs of the borings are shown on Plate 2 herewith.

24. The soil samples and data obtained by the explorations have been examined. Complete data relative to these explorations to be shown in the specifications and on the contract drawings are available.

25. The exploration data show that the overburden soil in the foundation areas of the structures and in the anchorage areas is mainly sandy gravel and gravelly sand underlying a surface deposit of silt and sand soils containing large and significant percentages of coal, coal dust, wood chips, organics, shells and offensively odorous material. The surface deposit in the anchorage area varies in depth from 2 to 10 feet and the material in this deposit will compose the major portion of the material to be excavated. The surface deposit in the foundation areas varies in thickness from 0 to 5 feet with no significant thickness at the location of Holes FD-1 and FD-2. The compaction and silt content of the material in the underlying sand and gravel deposit increase with depth and near the rock surface in some areas the soil is a moderately compact gravelly silty sand.

26.. The bedrock in the foundation and anchorage areas is basalt. The rock is fine grain and dense. It shows very little weathering and only a moderate amount of jointing. The rock in the main is amygdaloidal; that is, the original vesicles in the rock have been filled by secondary minerals.

27. An investigation has been made to determine the availability of suitable materials for fill within sheet pile walls. Two large gravel deposits containing clean gravelly sand exist in the vicinity of Pembroke, Maine. There appears to be no adequate available source of free draining granular material on Moose Island. Suitable bedrock is exposed at two inactive quarries on Moose Island and at other locations on the island, particularly along the shore. One of the quarries is located on the west shore of the island. Suitable bedrock is also exposed along the shore of the mainland north of Lubec. All of these bedrock sources are suitable for a quarrying operation. Little if any stripping would be required and working faces would be adequate for an economical operation. Glacial till which is non-free draining material can probably be obtained on the mainland within several miles of the shore. In general, the glacial till deposits near the shore and in available areas on Moose Island are too thin for an economical operation.

28. On the basis of the above described explorations and materials survey, considering the design features of the proposed structures and the proposed excavation operations, it is recommended that the following assumptions and data be used for design and design studies:

a. Foundations

(1) No stripping or excavation will be required to produce satisfactory foundation conditions for sheet pile structures.

(2) Sheet piling for walls should extend at least 10 feet into overburden soil to provide adequate foundation seepage control and to confine the surface deposit material.

(3) The foundation overburden material has an angle of internal friction of 30 degrees and a submerged unit weight of 60 pounds per cubic foot, except that the soil in the surface deposit (see Paragraph 25) will have negligible passive resistance against the outside of the structure.

(4) The surface soil in the foundation area of the stone approach will consolidate to provide a stable foundation. Construction of the stone approach above an elevation of approximately 21 feet above mean low water will be deferred to provide time for the consolidation of the foundation soil.

b. Anchorage

- (1) Most of the material to be excavated is not suitable for fill material between the sheet pile walls.
- (2) All overburden soil can be easily dredged.
- (3) It is expected that no bedrock will be encountered in the proposed excavation.

c. Fill Material

- (1) Clean free draining gravelly sand or sandy gravel can be obtained from natural sources which will require a truck haul distance of 14 miles.
- (2) Suitable rock fill may be obtained by quarrying from sources requiring a 3-mile truck haul.
- (3) Non-free draining glacial till can be obtained from sources requiring a truck haul distance of 11 miles.
- (4) All fill material will be from sources selected and furnished by the contractor.
- (5) Specific Data:

<u>Material</u>	<u>Unit Weights</u> lb./cu. ft.		<u>Angle of</u> <u>Internal Friction</u> <u>Degrees</u>
	<u>Sub.</u>	<u>Sat.</u>	
Free draining sand or gravel	50	115	30
Quarry-run rock	50	115	40
Non-free draining glacial till	40	105	20

There are some indications that the surface of the bedrock may rise west of drill hole FD-6.

SHORE LINE CHANGES

29. The plan of improvement considered herein would have no effect on the shore line of the harbor.

DESCRIPTION OF PROPOSED STRUCTURE

30. Federal Breakwater. - The Federal breakwater located off shore between the Holmes Wharf and the Wardsworth dock will have a total length of 490 feet and a top elevation of 26 feet above mean low water. It will be 420 feet long and 50 feet wide parallel to

the waterfront with its north end turned at right angles toward shore for a distance of 70 feet and a width of 40 feet. Its construction will consist of a double row of steel sheet piling stiffened with steel channel wales and tied together with two rows of steel tie rods. Type Z-32 steel piling will be used for the construction of the 420-foot portion parallel to the waterfront and type Z-27 steel piling will be used for the construction of the north portion which is turned toward shore. Two 12-inch 30-pound channel wales will be fastened to the inside of each wall at elevation +2.0 and two 12-inch 25-pound channel wales will be fastened to the inside of each wall at elevation +16.0. The lower group of tie rods at elevation +2.0 will be 2 3/4 inches in diameter and spaced on 7.5-foot centers and the upper group of tie rods at elevation +16.0 will be 1 3/4 inches in diameter and spaced on 15-foot centers.

Specifications will state that an adequate and approved system of temporary supports will be furnished to hold the steel sheet walls in line during construction and to support the tie rods during filling operations. In addition, placement of rock fill must follow along closely with the erection of the sheet pile walls to provide stability to the structure as the construction progresses.

31. The inside of the breakwater will be filled with quarry-run stone topped with gravel base and 2-inch cold-mix bituminous gravel paving. A 10-inch x 12-inch timber guard will cap the top of each row of sheet piling.

32. Public Landing. - The Public Landing connecting the breakwater to shore consists of a stone approach and steel faced pier with a top elevation of 26 feet above mean low water. The stone approach is 100 feet long with a top width of 35 feet extending from the existing wall to the steel faced pier. The steel faced pier will extend for a length of 140 feet and a width of 40 feet connecting the stone approach with the Federal Breakwater. Its construction will consist of a double row of steel sheet piling stiffened with steel channel wales and tied together with one row of steel tie rods. Type Z-27 steel piling will be used for the steel faced pier. Two 12-inch 30-pound channel wales will be fastened to the inside of each wall at elevation +6.0. One row of tie rods at elevation +6.0 will be 2 3/4 inches in diameter and spaced on 7.5-foot centers.

33. The inside of the steel faced pier will be filled with quarry-run stone, topped with gravel base and 2-inch cold-mix bituminous gravel paving. A 10-inch x 12-inch timber guard will cap the top of each row of sheet piling.

34. The sizes of tie rods and channel wales for both the Federal Breakwater and the Public Landing are to be adjusted and spaced according to the section of the steel sheet piling to be used and according to the variation in height of the structure.

35. The stone approach portion of the public landing will be constructed of quarry-run stone, the larger sizes to be used on the outside slopes. The slopes will be 1 vertical on $1\frac{1}{2}$ horizontal. The stone approach will be topped with a gravel base and a 2-inch cold-mix bituminous gravel paving. Guard rails will be constructed on each side of the roadway across the stone approach.

36. A timber fender system will be constructed along each face of the steel faced pier and Federal Breakwater. The fenders will consist of 10-inch x 10-inch timbers spaced 10.5 feet apart fastened to the steel sheet piling by 6 x 4 x $\frac{1}{2}$ -inch angles and bolted at the top to the timber guard. Every third fender will be 2 feet above the timber guard to be used for mooring lines.

37. Mooring cleats and mooring rings will be installed where needed. Steel runged ladders will also be installed where necessary. Provision for 16 ladders has been allowed in the cost estimate.

38. Dredging. - The material from the 10 and 14-foot Federal Anchorages and 10-foot Berths will be removed by bucket dredge and deposited in deep water in Friar Roads. It is believed that a crane floated on a scow will be used to accomplish the required dredging.

AIDS TO NAVIGATION

39. The U. S. Coast Guard has been consulted and has indicated the proposed breakwater would require no aids to navigation.

STRUCTURAL DESIGN

40. Purpose and Scope. - This section of the design memorandum presents the design criteria, basic data, and assumptions used in the structural design of the Federal Breakwater and Public Landing structures. A brief description of the structures with loading conditions and assumptions used is included to show the design procedure. Typical computations are included as Exhibit A showing the maximum conditions.

41. Design Criteria.

a. General. - Allowable working stresses conform to those specified in the Engineering Manual EM 1110-1-2101 "Working Stresses for Structural Design". General design assumptions and criteria are

based on other applicable parts of the Engineering Manual for Civil Works: Design of Breakwaters and Jetties (EM 1110-2-2904); Design of Pile Structures and Foundations (EM 1110-2-2906); and Hydraulic Design, Waves and Wave Pressures (Part CXVI, Chapter 8). Technical Report No. 4 "Shore Protection Planning and Design" by the Beach Erosion Board was used in the determination of wave forces. Technical Monograph No. 75 volume I "Steel Sheet Piling Cellular Cofferdams on Rock" of the Tennessee Valley Authority and Paper No. 1366 of the American Society of Civil Engineers Journal of Waterways and Harbors Division dated September 1957 were used in stability computations of earth filled cells.

b. Structural Steel. - Structural steel was designed for the working stresses of A7 steel (Y.P. = 33,000 p.s.i. min.) which conforms to the "Specifications for the Design, Fabrication and Erection of Structural Steel for Buildings" of the American Institute of Steel Construction. Normal working stresses have been used for the design loading condition of the fill material. No allowance for corrosion has been made other than using sections with a minimum of 3/8 inch thickness.

42. Basic Data and Assumptions.

a. Breakwater Structure and Wave Data.

Top of structure	el. + 26
Foundation bottom	el. - 23
Design still water level	el. + 23
Significant wave height	7.0 ft.
Maximum wave height	11.1 ft.
Significant wave period	5.6 sec.
Depth of water at still water level	46 ft.
Deep water wave length	161 ft.

b. Public Landing Structure and Wave Data.

Top of structure	el. + 26
Foundation bottom	el. - 11
Design still water level	el. +23
Significant wave height	7.0 ft.
Maximum wave height	11.1 ft.
Significant wave period	5.6 sec.
Depth of water at still water level	34 ft.
Deep water wave length	161 ft.

c. Loads. - The following loads and unit weights were used:

Live load on top of structure	300 #/s.f.
-------------------------------	------------

Sea water
Fill material (rock)

64.2 #/cu.ft.

submerged
saturated

50 #/cu.ft.
115 #/cu.ft.

d. Wind, Earthquake Forces, and Ice Pressure. - These forces were not considered as factors in the design and were disregarded.

43. Stability. - A one-foot width of the parallel-wall sheet pile structure for the breakwater and landing was investigated for stability under a loading condition of a non-breaking wave with still water at the maximum high water level of el. + 23. The structures were assumed to be founded on rock with the resultant falling within the middle 1/3 of the base and the sliding coefficient determined to be less than an assumed coefficient of friction of 0.5. An additional factor of safety for stability was assumed to be obtained by the sheet pile penetration into the foundation subsoil. The stability was further checked by a method using the vertical shear and shear resistance of the fill material as outlined on Pg. 92 of TVA Technical Monograph No. 75. Another check on stability was made using Cummings' method as outlined in Paper No. 1366 of the ASCE Journal of Waterways and Harbors Division.

44. Design. The steel sheet pile section was designed for an internal loading of saturated and submerged rock with the tide at maximum low water elev. -4. No internal hydrostatic pressure was used as the fill material was assumed to drain through the interlocks as the tide fell. Consideration will be given to properly spaced and sized drain holes in the final design. Channel wales and tie rods were designed to stiffen and tie the two parallel sheet pile walls together.

SOURCES OF CONSTRUCTION MATERIALS

45. The important construction materials required for construction of the Federal breakwater and Public Landing can be obtained from the following sources:

a. Quarry-Run Stone. - The following inactive quarries can be considered as rock sources:

(1) Johnson Cove Quarry. - Moose Island. This quarry was opened as a rock source for the Passamaquoddy Project in 1936. The quarry is located just off the highway and easily accessible, being a haul distance of about three miles. The required yardage for the project is available at this source.

(2) Shackford Head Quarry. - This quarry is situated at Shackford Head, a high promontory on the south side of Moose Island. The access road to this quarry is steep and rocky and will require additional work to make it available for truck haul.

b. Gravel. - Gravel materials for the pavement and base exist in natural deposits within 14 miles of the site.

PUBLIC RECREATIONAL USE

46. No pleasure boats are based at Eastport but an average of 100 visiting pleasure boats are reported to call at the Wardsworth wharf each boating season. It is expected the proposed improvement would be utilized by some visiting boats for convenient docking, overnight stops, and possibly to seek refuge during storms while they are cruising nearby. There is no indication that any substantial benefit to recreational craft would result from the improvement.

REAL ESTATE REQUIREMENTS

47. The Federal breakwater will be located off shore. The Public Landing will be connected from the breakwater to shore. The city of Eastport has a Warranty Deed proving ownership of the land upon which the Public Landing is to be constructed.

RELOCATIONS

48. The construction of the Public Landing will require removal or relocation of sewer lines that discharge into the harbor. These lines carry surface drainage from the hillside of part of the city and domestic sewerage from several residences. City officials have indicated that these sewer outlets have been a nuisance to the city of Eastport for some time and eventually measures would have to be taken by the city to relocate the sewers. This feature will be taken care of by the city either before the Federal breakwater and Public Landing are constructed or during their construction.

COST ESTIMATES

49. Cost Summary - Project Plan. - A summary of the estimated Federal and non-Federal costs for the project plan as considered in this design memorandum at current January 1961 price levels is as follows:

a. Federal Costs.

09	CHANNELS	
	14 & 10-ft. Anchorage	\$ 40,000
10	BREAKWATERS	493,000
29	PREAUTHORIZATION STUDIES	10,000
30	ENGINEERING AND DESIGN	22,000
31	SUPERVISION AND ADMINISTRATION	40,000
	TOTAL COSTS (Federal Funds Only)	\$ 605,000

b. Non-Federal Costs.

	CHANNELS	
	10-ft. Berths	\$ 10,300
	Public Landing	124,200
	Fish Pump*	2,500
		\$ 137,000
	ENGINEERING & DESIGN	3,000
	SUPERVISION & ADMINISTRATION	10,000
	TOTAL COSTS (Non-Federal)	\$ 150,000

* Fish Pump to be purchased and installed by Local Interests under a separate contract.

50. Detailed Breakdown of Cost Estimate - Project Plan. A detailed estimate for the major feature costs for the project plan at current January 1961 price levels is as follows:

a. Cost to Corps of Engineers.

(1)	Furnish and place type Z-32 steel sheet piling - 1,810,000 lb. @ \$0.14	\$ 253,400
(2)	Furnish and place type Z-27 steel sheet piling - 204,000 lb. @ \$0.15	30,600
(3)	Furnish and place channel wales - 108,000 lb. @ \$0.20	21,600
(4)	Furnish and place tie rods and turn-buckles (including supports) - 80,000 lb. @ \$0.30	24,000
(5)	Furnish and place miscellaneous nuts, bolts and washers - Lump Sum	6,000
(6)	Furnish and place riprap stone - 450 cy @ \$3.00	1,400

(7)	Furnish and place stone fill in breakwater-38,000 cy @ \$2.50	\$ 95,000
(8)	Furnish and place bituminous gravel paving including gravel base-2,700 sq. yd. @ \$1.50	4,000
(9)	Furnish and place timber guard on top of breakwater - 1,040 lin. ft. @ \$3.85	4,000
(10)	Dredging 14 & 10-ft. anchorage-20,000 cy silt, sand & gravel @ \$1.80	<u>36,000</u>
		\$ 476,000
	Contingencies 12%	\$ 57,000
	Total Construction Costs	533,000
	Preauthorization Studies	10,000
	Engineering & Design	22,000
	Supervision & Administration	<u>40,000</u>
		\$ 605,000

b. Cost to Local Interests.

(1)	Furnish and place stone for stone approach - 5,500 cy @ \$2.50	\$ 13,700
(2)	Furnish and place type Z-27 steel sheet piling - 360,000 lb. @ \$0.15	54,000
(3)	Furnish and place channel wales - 17,000 lb. @ \$0.20	3,400
(4)	Furnish and place tie rods and turnbuckles (including supports) - 16,000 lb. @ \$0.35	5,600
(5)	Furnish and place miscellaneous nuts, bolts and washers - Lump Sum	2,000
(6)	Furnish and place stone fill in steel faced pier - 6,000 cy @ \$2.50	15,000
(7)	Furnish and place bituminous gravel paving including gravel base - 900 sq.yd. @ \$1.50	1,400
(8)	Furnish and place timber guard on top of steel faced pier - 280 lin.ft. @ \$3.85	1,100

(9)	Furnish and place guard rail on top stone approach - 200 lin.ft. @ \$3.00	\$ 600
(10)	Furnish and place wooden fenders on Federal Breakwater and Public Landing (including steel angles and bolts) - 32MFBM @ \$300	9,600
(11)	Furnish and place mooring cleats and rings - Lump Sum	900
(12)	Furnish and place steel rung ladders - 16 @ \$75 ea.	1,200
(13)	Dredging 10-foot berths - 5,000 cy silt, sand & gravel @ \$1.80	9,000
(14)	Furnish and install fish pump - Lump Sum	<u>2,500</u>
		\$ 120,000
	Contingencies 14 $\frac{1}{2}$ % (Fish Pump not incl.)	<u>17,000</u>
		\$ 137,000
	Engineering & Design	3,000
	Supervision & Administration	<u>10,000</u>
		\$ 150,000

51. Comparison of Federal Cost Estimates. - A comparison between current estimates and previous estimates is as follows:

	Project Document <u>Estimate</u> <u>Dec 1959</u>	Latest Approved <u>Estimate</u> <u>Sept 1960</u>	Project Plan As Considered In This Design <u>Memorandum</u> <u>Jan 1961</u>
09 CHANNELS			
14 & 10 ft. anchorage	\$ 30,000	\$ 30,000	\$ 40,000
10 BREAKWATERS	525,000	525,000	493,000
29 PREAUTHORIZATION STUDIES	10,000	10,000	10,000
30 ENGINEERING & DESIGN	10,000	10,000	22,000
31 SUPERVISION & ADMINIST.	<u>30,000</u>	<u>30,000</u>	<u>40,000</u>
	\$605,000	\$605,000	\$605,000

52. The increase in engineering and design from \$10,000 to \$22,000 is attributable to additional investigations and studies required which were not anticipated at the time the project document estimate was made.

SCHEDULE FOR DESIGN AND CONSTRUCTION

53. It is expected that the design will be completed and that plans and specifications will be approved and ready for advertising on or about 1 May 1961. The work can be advertised by 1 May 1961, contract awarded by 1 June 1961 with construction initiated by 15 June 1961 and completed by November 1961. All the work will be done and materials obtained under one continuing contract.

54. Funds available and recommended for the Federal and non-Federal features of the improvement, based on the above schedule for construction are as follows:

<u>Federal funds</u>	
Allotments to date	\$310,000
Funds to complete required in FY 1962	<u>295,000</u>
	\$605,000
 <u>Non-Federal</u>	
Allotments to date	\$ 3,000
Required prior to advertising the work	<u>144,500</u>
Total	\$147,500*

*Exclusive of \$2,500, cost of fish pump to be installed by local interests.

OPERATION AND MAINTENANCE

55. The harbor facilities will be operated by local interests at no cost to the Federal Government. The only operation costs to local interests will be the cost of supervision of the harbor and operating costs of their fish pump when it is in operation. The annual Federal maintenance items will include condition studies, repairs to breakwater and maintenance dredging in the anchorages. The total annual Federal charge for maintenance is estimated at \$1,600. The annual local maintenance items will include maintenance dredging in their berths, repairs to the Public Landing, repairs to the fendering system along the Public Landing and Federal Breakwater, repairs to fish pump and repairs to the breakwater paving when damage occurs from excessive use. No monetary evaluation has been made for local maintenance charges.

BENEFITS

56. The city of Eastport is important as one of the major centers of the nation's sardine canning industry and as a summer colony. There are 7 canneries and 5 reduction plants in Eastport that utilize the fish caught in the area. Commerce at Eastport Harbor averaged about 66,500 tons annually during the period 1952 through 1957, of which over 50 percent was in fish and fish products. In addition to this reported commerce, 60,000 to 90,000 passengers annually are landed at Eastport. The commerce at Eastport is expected to increase in the future as a result of normal population increase and in the event the Passamaquoddy power project is built, the commerce of Eastport would reasonably be several times the present commerce. The highly exposed nature of the harbor, together with the frequency of relatively high winds, makes it difficult or impossible to land fish or other cargo, with consequent loss through delay. As there is no protected anchorage along the waterfront, it is necessary for fishing vessels to anchor at remote points with consequent loss of time. In addition, during easterly, northeasterly or southeasterly storms which predominate, boats must be moved to the opposite side of the island as berths along the waterfront are unsafe during such storms. The only protection owners of small boats have in rough weather is to beach their boats. As a customs port, Eastport Harbor is used by large numbers of transient vessels, commercial fishing boats built in Nova Scotia entering through Eastport, and foreign entries and clearances through the port exceeding those in any other port in Maine. The improvement will permit the landing of fish now lost due to inability to land in stormy weather, save time now spent traveling from ports more distant from the fishing grounds, provide protected anchorage area and facilitate the handling of mail, cargo and passengers.

57. The benefits to be derived from the recommended improvement of Eastport Harbor are as follows:

Increased fish catch	\$66,000
Reduced operating cost for moving boats to sheltered anchorage	14,000
Reduced losses from storm damage to boats, cargo and equipment	3,000
Reduced cost of handling mail, cargo and passengers	<u>1,000</u>
Total benefits	\$84,000

The benefits are the same as those evaluated in the Project Document. The benefit-cost ratio is 2.5 to 1.

58. The annual charges based on the estimated costs are as follows:

a. Federal

(1) <u>Federal Investment</u>	\$605,000
(2) <u>Federal Annual Charges</u>	
Interest (0.025) (\$605,000)	\$ 15,100
25-year Amortization (0.02928)(\$605,000)	17,700
Maintenance	<u>1,600</u>
	\$ 34,400

b. Non-Federal

(1) <u>Non-Federal Investment</u>	\$150,000
(2) <u>Non-Federal Annual Charges</u> (Self liquidating)	<u>0</u>

c. <u>Total Federal and Non-Federal</u> <u>Annual Charges</u>	\$ 34,400
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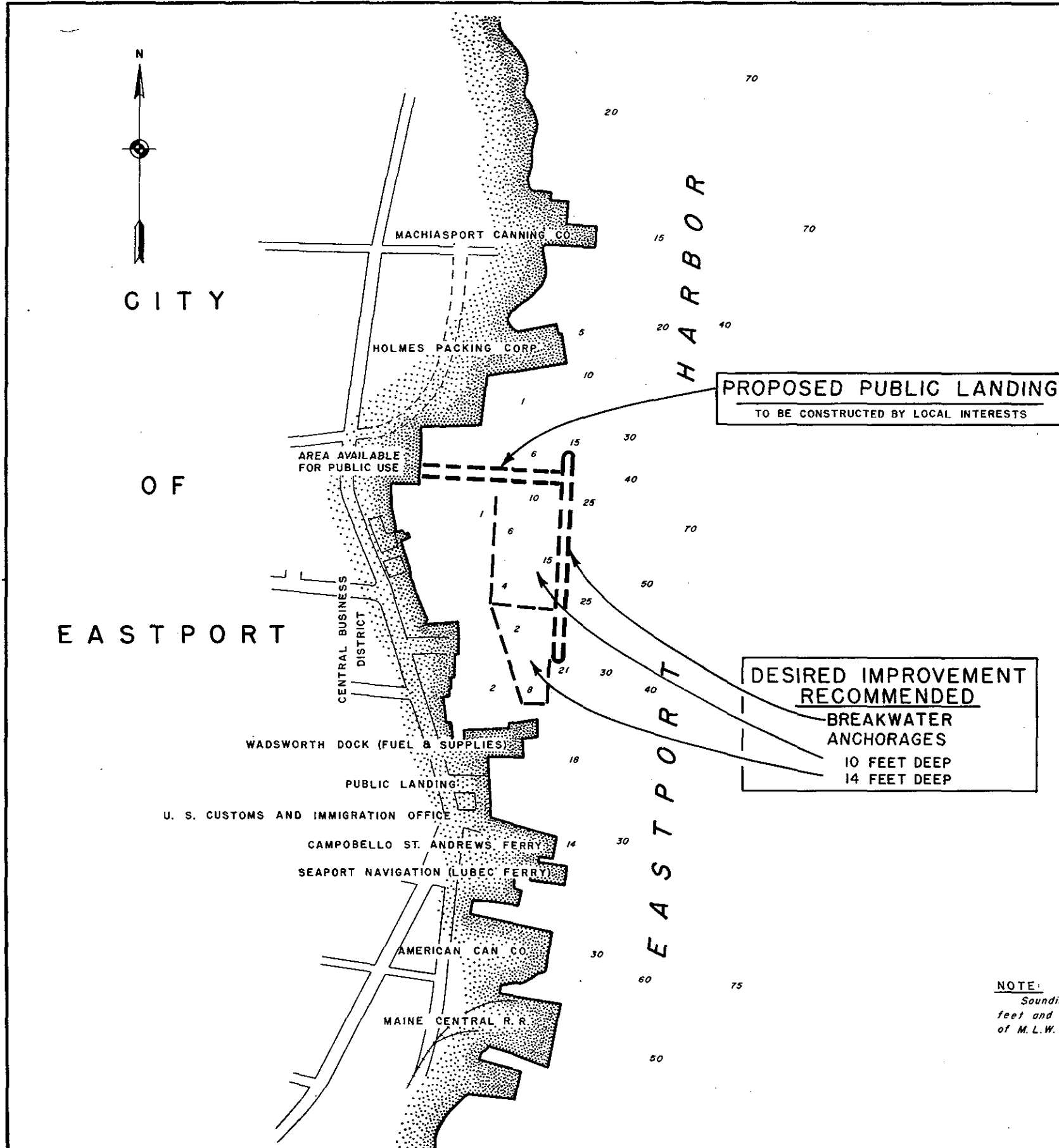
RECOMMENDATION

59. It is recommended that the project plan for the Federal Breakwater and Anchorage as described herein be approved.

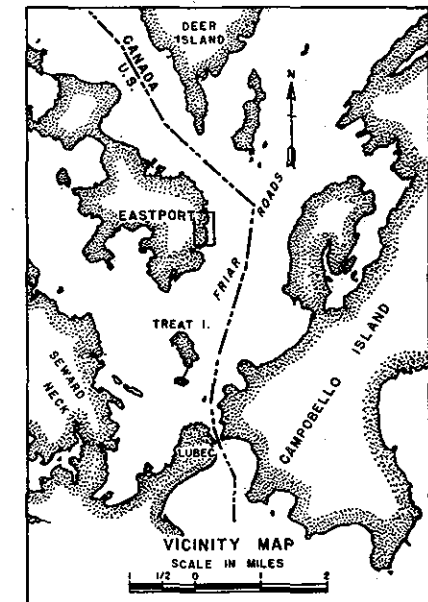
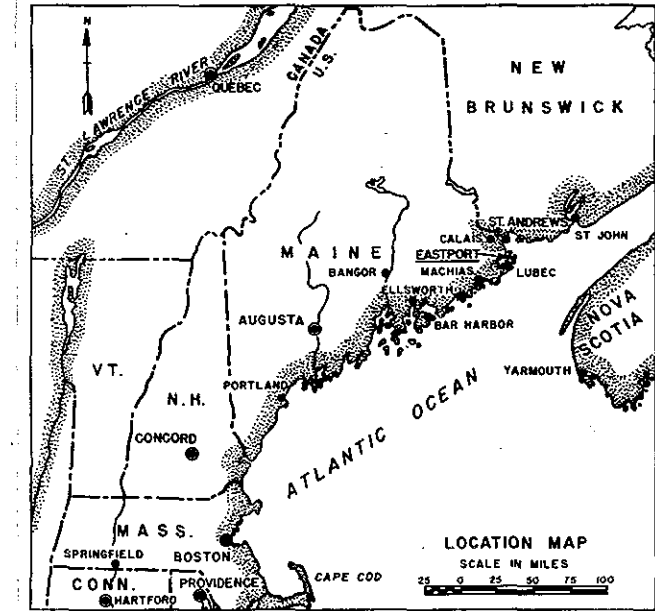
60. It is further recommended that the design of the Public Landing joining the breakwater to shore with berths, necessary fendering and mooring facilities described herein be approved.

6 Incl

1. Plate 1 - Project Document Plan, June 1959
2. Plate 2 - Project Plan & Subsurface Explorations
3. Plate 3 - Sections & Details
4. Plate 4 - Wind & Wave Exposure Diagram
5. Exhibit A - Structural Design Computations
6. Exhibit B - Wave Study for Breakwater Design

**NOTE:**

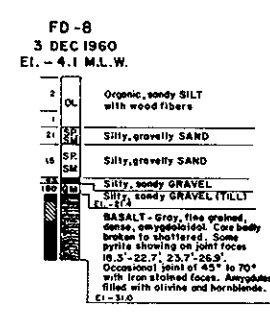
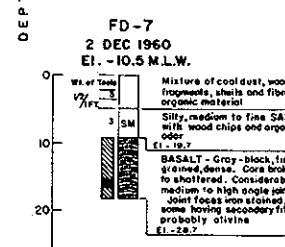
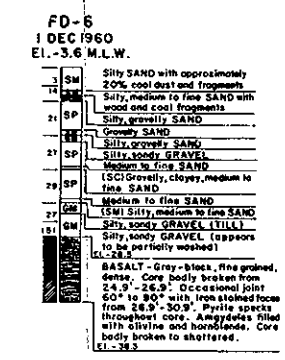
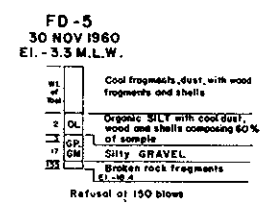
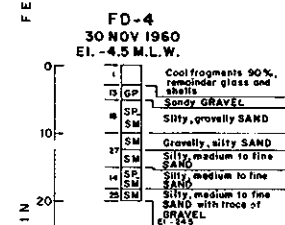
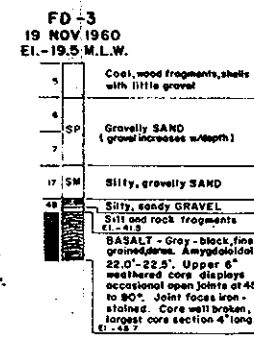
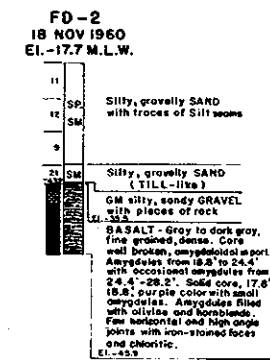
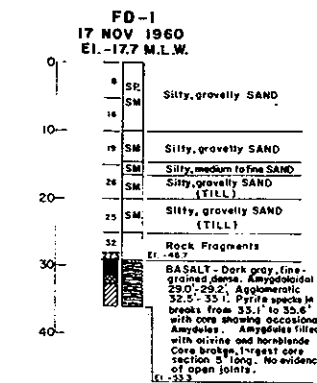
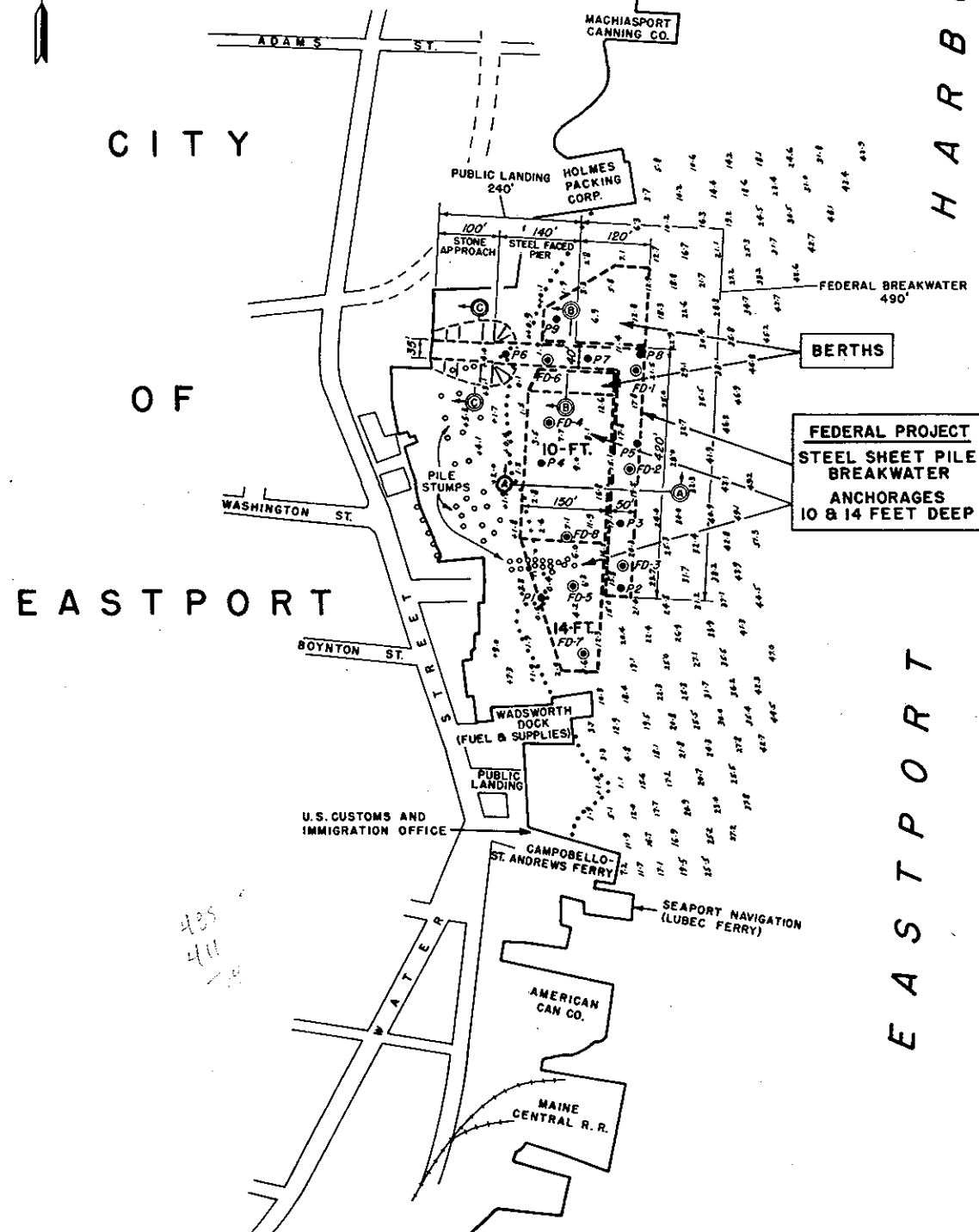
Soundings shown thus, 15, are in feet and are referred to the plane of M. L. W.

**EASTPORT HARBOR MAINE**

IN 1 SHEET		SCALE IN FEET	
100 0 100 200 300 400 500			
NEW ENGLAND DIVISION, WALTHAM, MASS. JUNE 1959			
APPROVED:	BY: <i>W. F. [Signature]</i>	APPROVED:	BY: <i>[Signature]</i>
SUBMITTED:	BY: <i>[Signature]</i>	BY: <i>[Signature]</i>	TO ACCOMPANY SURVEY
CH. PLANNING DIVISION	CH. BY: <i>[Signature]</i>	REPORT DATED:	JULY 17, 1959
CH. PLANNING DIVISION	CH. BY: <i>[Signature]</i>	FILE NO.	1418 D-9-4
CH. PLANNING DIVISION	CH. BY: <i>[Signature]</i>		

LIST OF PROBINGS				
NUMBER	DEPTH OF WATER	DEPTH OF PENETRATION	ELEVATION BELOW M.L.W.	
1	1.0	0.0	1.0	Refusal
2	19.6	22.6	3.0	
3	19.5	25.1	5.6	
4	5.7	12.6	6.9	
5	10.1	24.7	6.6	
6	0.2	5.3	5.1	
7	9.7	21.7	12.0	No "
8	19.5	29.5	10.0	No "
9	3.8	9.7	5.9	Refusal

Probing survey by J. Rock, April 22, 1959 by wash method, using 1-1/2" centrifugal pump reduced to 3/4" probing pipe.



LEGEND FOR GRAPHIC LOGS

- FD-6**
1 DEC 1960
El. -3.6 M.L.W.
- Foundation Test Boring
Date exploration completed
Elevation of ground surface during time of exploration
- Group letter symbol according to Unified Soil Classification System
- Number of blows per foot of penetration using a 350 pound hammer falling freely on average of 18 inches on the sample spoon of the size indicated and equipped with a beveled drive shoe
- Fractional foot of penetration indicated as follows: number of blows / tenths of a foot 150/3
- Rock symbol
EL. - 28.5 Elevation of bedrock surface
Rock core recovery 0-25 %
Rock core recovery 25-50 %
Rock core recovery 50-75 %
Rock core recovery 75-90 %
Rock core recovery 90-100 %
EL. - 38.3 Elevation bottom of exploration

NOTES

Soundings, borings and probings are in feet and tenths and are referred to the plane of Mean Low Water. Hydrography from survey of Jan. 26-Feb. 6, 1957 by J. Rock.
Field books: R & H. 1167, 1168, 1169 & 1368.
See Plate 3 for sections and details.

LEGEND

MEAN HIGH WATER ————
MEAN LOW WATER
PROBINGS SHOWN THUS ● P1
FOUNDATION TEST BORING ● FD-1

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

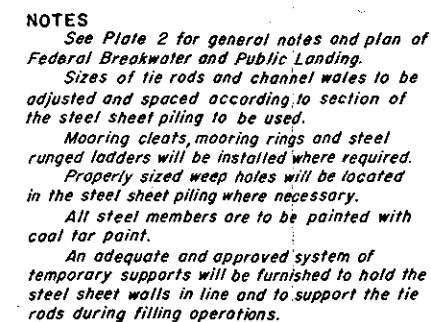
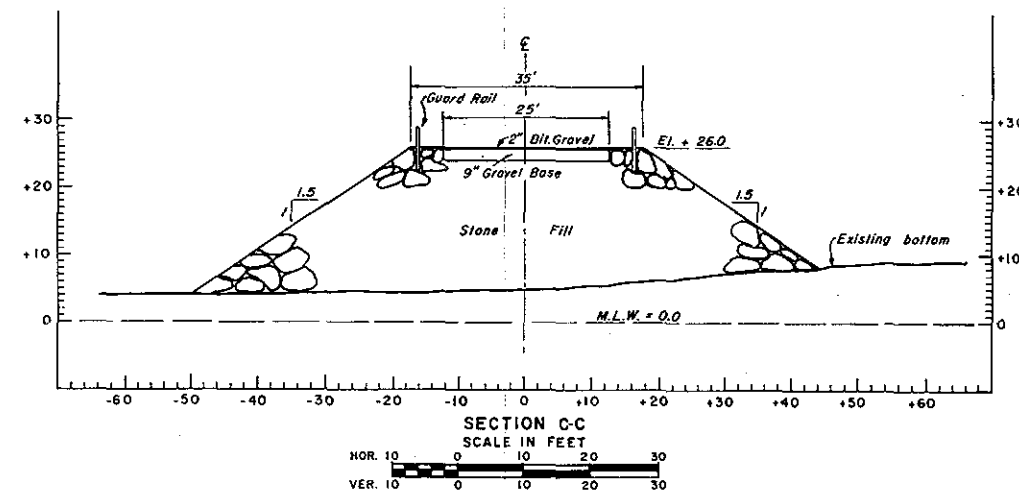
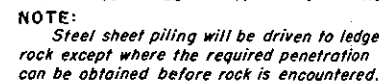
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PROJECT PLAN & SUBSURFACE EXPLORATIONS**
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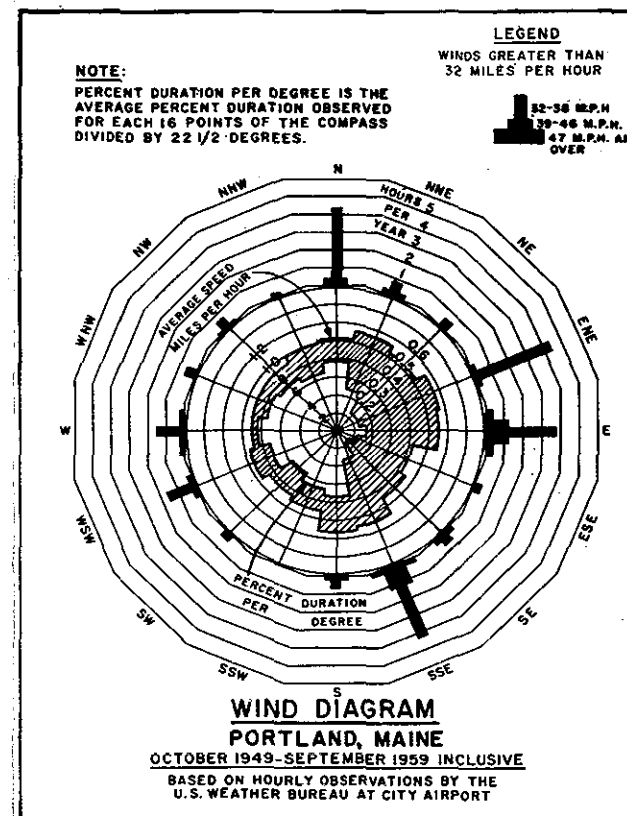
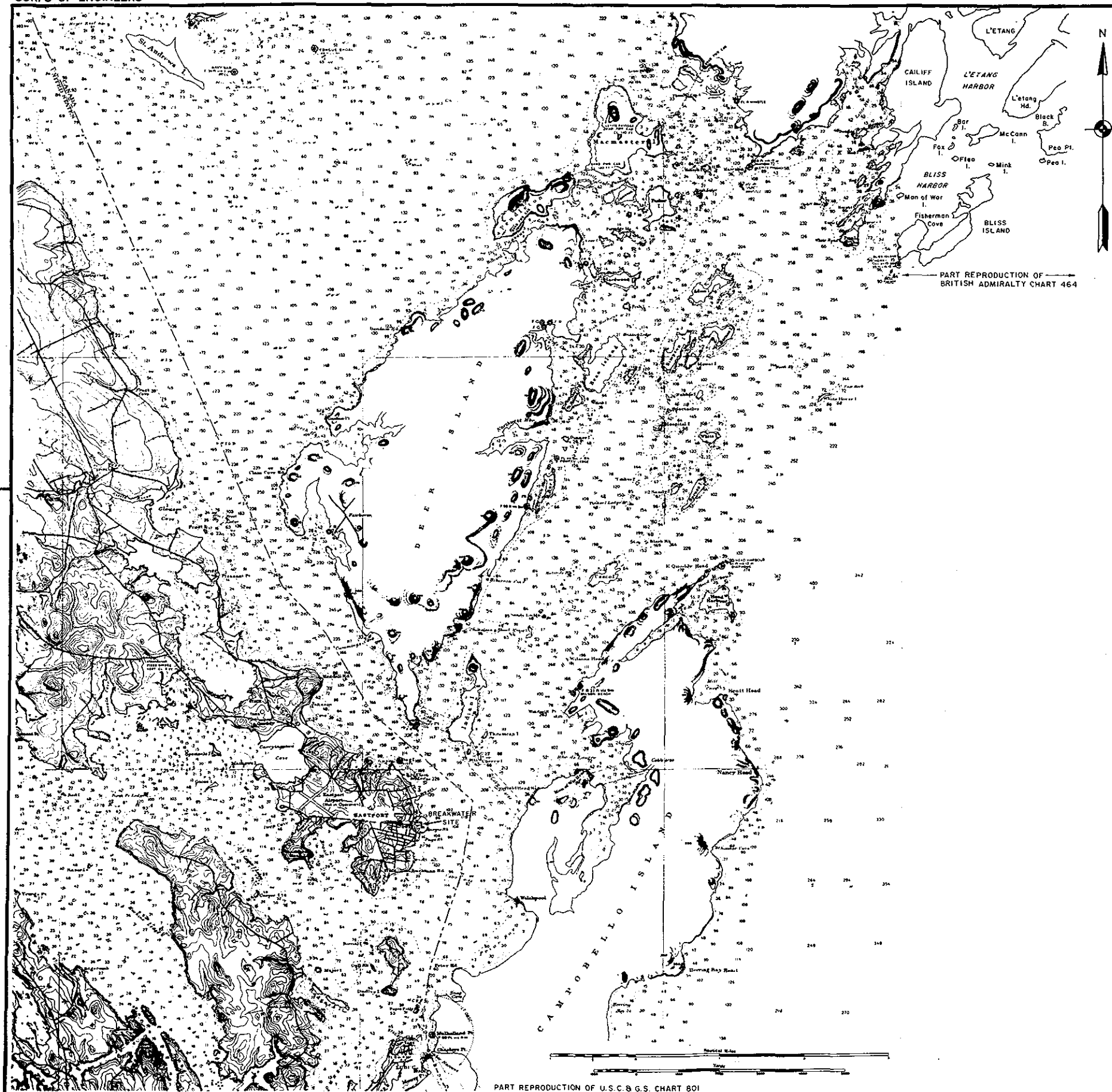
DATE FEB. 1961

TO ACCOMPANY DESIGN MEMO
DATED: MARCH 1961

DRAWING NUMBER
1466 D-9-4

SHEET 1 OF 2

[illegible]



REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

**EASTPORT HARBOR
MAINE**
WIND & WAVE EXPOSURE DIAGRAM

DR. BY: ADC CK. BY: SSA
PROJECT ENGINEER
APPROVED: [Signature] DATE: FEB. 1961
CHIEF ENGINEERING DIV.

TO ACCOMPANY DESIGN MEMO
DATED: MARCH 1961

SCALE AS SHOWN
DRAWING NUMBER
1467 D-9-4
SHEET 1 OF 1

GENERAL DESIGN MEMORANDUM
FOR
CONSTRUCTION OF A BREAKWATER
AT
EASTPORT HARBOR, MAINE

EXHIBIT A
STRUCTURAL DESIGN COMPUTATIONS

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
COPRS OF ENGINEERS WALTHAM, MASSACHUSETTS
MARCH 1961

SUBJECT EASTPORT HARBOR MAINE
 COMPUTATION Breakwater Stability
 COMPUTED BY GTS CHECKED BY C.C.C. DATE 1/30/61

DESIGN DATA

Significant wave height - 7.0 ft.
 Period - 5.6 sec (T)
 Deep water wave length - 161 ft (L₀)
 Max wave height = $7 \times 1.58 = 11.1$ ft (H)
 Max. high water level - el +23'
 Bottom elev. @ structure - el -23'
 Depth of water @ structure - 46 ft (d)
 Top of structure - el +24'
 Wgt. of salt water - 64.2 #/ft³

Wave type [ref EM 1110-2-2904 p.7 par 4-09b]

Max wave height - 11.1 ft.

$$11.1 \times 1.3 = 14.4 \text{ ft.}$$

$$\text{water depth} = 46 \text{ ft} > 14.4'$$

∴ wave is non-breaking type.

Force Due to Non-breaking Wave

Ref. Beach Erosion Board - Technical Report No. 4
 Shore Protection Planning & Design Table D-1

$$\frac{d}{L_0} = \frac{46}{161} = 0.2857 \quad \frac{d}{L} = 0.2993$$

$$L = \frac{46}{0.2993} = 154'$$

$$\begin{aligned} h_0 &= \frac{\pi H^2}{L} \coth \frac{2\pi d}{L} \\ &= \frac{\pi (11.1)^2}{154} \times \frac{1}{.9546} \\ &= 2.6' \end{aligned}$$

$$\begin{aligned} P_1 &= \frac{w H^3}{\cosh \frac{2\pi d}{L}} \\ &= \frac{64.2 (11.1)^3}{3.356} \\ &= 212 \pi / \text{sf} \end{aligned}$$

SUBJECT EASTPORT HARBOR MAINE

COMPUTATION Breakwater Stability

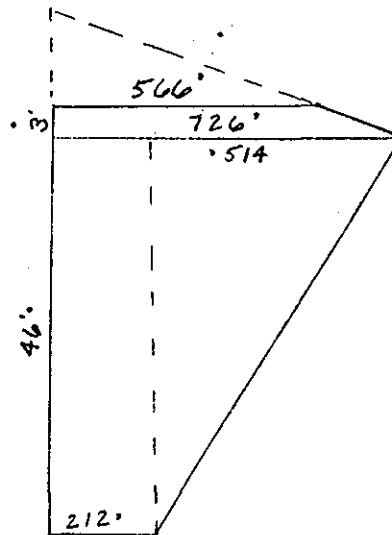
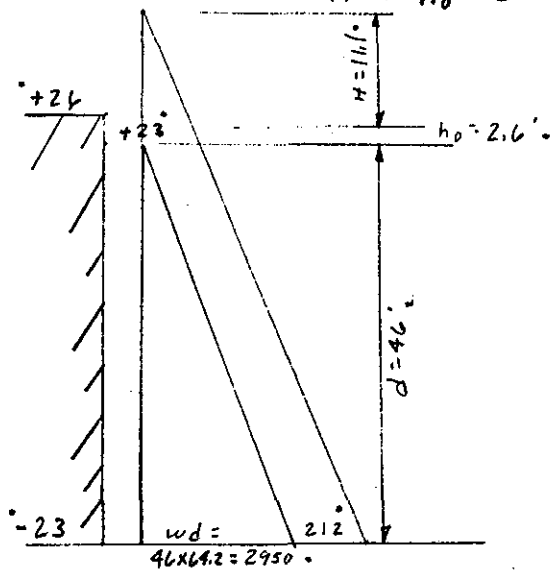
COMPUTED BY GTS

CHECKED BY CCC

DATE 1/30/61

Crest of Clapotis

$$H' + h_0 + d = 11.1 + 2.6 + 46 = 59.7'$$



$$\frac{2950 + 212}{59.7} (10.7) = 566'$$

$$\frac{2950 + 212}{59.7} (13.7) = 726'$$

WAVE LOADING

$$\begin{aligned} 566 \times 3 &= 1,70' \\ \frac{1}{2} \times 160 \times 3 &= 0.24' \\ 212 \times 46 &= 9.76' \\ \frac{1}{2} \times 514 \times 46 &= 11.85' \\ \Sigma H &= 23.55' \end{aligned}$$

$$\begin{aligned} \times 47.5 &= 80.6' \\ \times 47' &= 11.3' \\ \times 23' &= 224.5' \\ \times 30.7' &= 363' \\ \Sigma M &= 679 \text{ ft} \cdot \text{k} \end{aligned}$$

27. Sept 49

CORPS OF ENGINEERS, U. S. ARMY

PAGE 3 of 23

SUBJECT EASTPORT HARBOR MAINECOMPUTATION Breakwater StabilityCOMPUTED BY GTS CHECKED BY C.C.C. DATE 1/30/61

Stability of Parallel-Wall Sheet Pile Cell.

CELL FILL MATERIAL.

Rock is assumed submerged $el - 23$ to $el + 23$.Rock is assumed saturated $el + 23$ to $el + 26$.

$$\gamma_{sat} = 115 \text{ }^{\pi}/\text{ft}^3.$$

$$\gamma_{sub} = 50 \text{ }^{\pi}/\text{ft}^3.$$

Total wgt. of cell (not including sheet pile)

x - width of structure

$$50(x)(46) + 115(x)(3) = \Sigma V$$

$$2645(x).$$

For case of resultant falling within middle $\frac{1}{3}$.

$$\Sigma V(e) = \Sigma M.$$

$$\frac{2645(x)(x)}{6} = 679,400.$$

$$x^2 = 1540.$$

$$x = 39.2'.$$

Sliding Coefficient

$$\frac{\Sigma H}{\Sigma V} = \frac{23.55}{2645 \times 39.2} = 0.23 < 0.5 \text{ [assumed coeff. of friction]}$$

Sheet piling penetration also affords resistance to sliding.

27 Sept 49

CORPS OF ENGINEERS, U. S. ARMY

PAGE 4 of 23

SUBJECT EASTPORT HARBOR MAINECOMPUTATION Breakwater StabilityCOMPUTED BY GTS

CHECKED BY

DATE 1/30/61

Width of Parallel-Wall Sheet Pile Cell.

use a factor of 0.8 considering structure is
a filled box without a bottom [EM 1110-2-2906 p.20]

$$\frac{39.2'}{0.8} = 49' \quad \text{say } 50 \text{ ft. width.}$$

VERTICAL SHEAR + SHEAR RESISTANCE.

ref. TVA Technical Monograph No. 75 Steel Sheet
Piling Cellular Cofferdams on Rock. p. 59-93.

total vertical shear (S_v).

$$\begin{aligned} \text{(p. 62)} \quad S_v &= \frac{3}{2} \times \frac{M}{b} \\ &= \frac{3}{2} \times \frac{679,400'}{50'} \\ &= 20,400 \cdot \# \end{aligned}$$

$$M = 679,400' \cdot \#$$

$$b = 50 \text{ ft.}$$

shear resistance (S).

$$P = \frac{1}{2} K \gamma H^2$$

$$\text{(p. 65)} \quad K = \frac{\cos^2 \phi}{2 - \cos^2 \phi}$$

$$\phi = 40^\circ \quad (\text{internal friction angle})$$

$$K = \frac{(.766)^2}{2 - (.766)^2} = 0.415$$

27 Sept 49

CORPS OF ENGINEERS, U. S. ARMY

PAGE 5 of 23

SUBJECT

EASTPORT HARBOR MAINE

COMPUTATION

Breakwater Stability

COMPUTED BY

GTS

CHECKED BY

DATE 1/30/61

$$P_{subm} = \frac{1}{2}(415)(50)(46)^2$$

$$= 22,000$$

$$P_{sat} = (415)(115)(3) \left[\frac{1}{2} \times 3 + 46 \right]$$

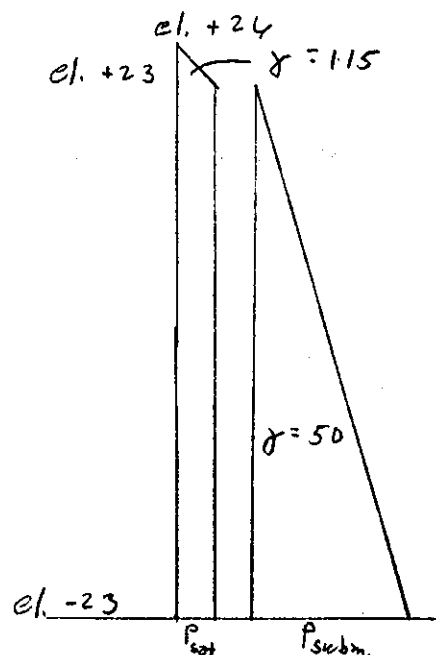
$$= 6800$$

$$\text{total } P = 28,800$$

$$S = P \tan \phi$$

$$= 28,800 (.839)$$

$$= 24,200$$



Factor of Safety

$$G_s = \frac{S}{S_v} \Rightarrow 1.25 \quad [TVA \text{ Tech. Monograph No. 75} \\ \text{p. 86}]$$

$$= \frac{24,200}{20,400}$$

$$= 1.19 < 1.25 \quad \text{N.G.}$$

Determine width of structure reqd for $G_s = 1.25$

$$S_v = \frac{24,200}{1.25} = 19,400$$

$$b \text{ (width)} = \frac{3}{2} \times \frac{M}{S_v}$$

$$= \frac{3}{2} \times \frac{679,400}{19,400}$$

$$= 52.5 \text{ ft. wide}$$

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SUBJECT

EASTPORT HARBOR MAINE

COMPUTATION

BREAKWATER Stability

COMPUTED BY

GTS

CHECKED BY

CCC.

DATE

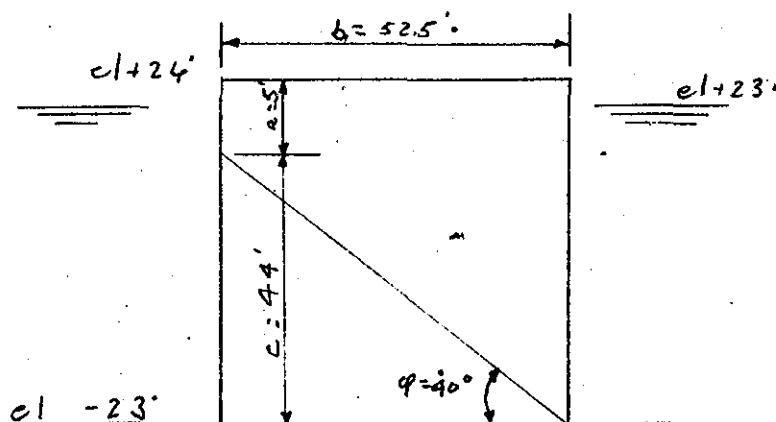
1/31/61

Check stability using Cumming's method Ref:
Journal of Waterways + Harbors Division ASCE Sept. 1957
paper 1366

Resisting moment (assumed as if on rock base).

$$M_2 = \gamma \left[\frac{ac^2}{2} + \frac{c^3}{3} \right]$$

[interlock tension not a factor in a parallel wall cell]



$$c = b \tan \phi$$

$$= 52.5 (0.839) = 44'$$

assume rock material is completely submerged

$$\gamma = 50 \text{ #/ft}^3 \quad \phi = 40^\circ$$

$$M_2 = 50 \left[\frac{5(44)^2}{2} + \frac{(44)^3}{3} \right] = 1662 \text{ ft-k}$$

Overturning moment due to wave loading

$$M_w = 679.4 \text{ ft-k}$$

Factor of safety

$$\frac{1662}{679.4} = 2.44 > 2.0$$

Revise width to 50' new FS = 2.28

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SUBJECT EASTPORT HARBOR MAINECOMPUTATION Cell Design - BreakwaterCOMPUTED BY GTSCHECKED BY C.C.C.DATE 1/31/61

CELL DESIGN CONDITION FOR INTERNAL LOADING

cell fill material (rock)

$$\phi = 40^\circ$$

$$\gamma_{sat} = 115 \text{ pcf} \quad \text{el. -4' to el. +26'}$$

$$\gamma_{sub} = 50 \text{ pcf} \quad \text{el. -4' to el. -23'}$$

min. L.W. @ elev. -4'

assume tie rods + hor. walers @ el. +2' + el. +16'

300 pcf surcharge on top of structure.

Lateral earth pressures.

$$P_e = \gamma_e \tan^2 \left[45^\circ - \frac{\phi}{2} \right]$$

saturated material

$$P = 115 (.466)^2 = 25 \text{ pcf}$$

Submerged material

$$P = 50 (.466)^2 = 11 \text{ pcf}$$

Replace 300 pcf surcharge with an additional 3' of fill material.

For design section consider deepest section with foundation bottom at el. -23'

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SUBJECT EASTPORT HARBOR MAINE
 COMPUTATION Cell Design - Breakwater
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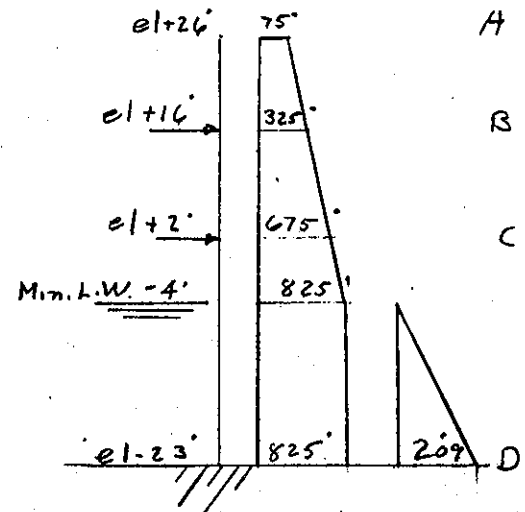
Lateral forces:

Sat. material:

$$\begin{aligned} 3 \times 25 &= 75 \\ 13 \times 25 &= 325 \\ 27 \times 25 &= 675 \\ 33 \times 25 &= 825 \end{aligned}$$

Subm. material:

$$19 \times 11 = 209$$



FEM'S

$$FEM_{BA} = \frac{75(10)^2}{2} + \frac{250(10)^2}{6} = 3750 + 4170 = 7.92 \text{ } ^{-K}$$

$$FEM_{BC} = \frac{325(14)^2}{12} + \frac{350(14)^2}{30} = 5308 + 2290 = 7.59 \text{ } ^{-K}$$

$$FEM_{CB} = \frac{325(14)^2}{12} + \frac{350(14)^2}{20} = 5308 + 3430 = 8.73 \text{ } ^{-K}$$

$$FEM_{CD} = \frac{825(25)^2}{12} - \frac{150(6)^2}{60(25)^2} \left[10(25)^2 - 10(6)(25) + 3(6)^2 \right] + \frac{209(19)^3}{60(25)^2} [125.5]$$

$$= 43,000 - 700 + 2600 = 45.0 \text{ } ^{-K}$$

$$FEM_{DC} = \frac{825(25)^2}{12} - \frac{150(6)^3}{60(25)^2} [5 \times 25 - 3 \times 6] + \frac{209(19)^2}{60(25)^2} [10(25)^2 - 10(25)(19) + 3(19)^2]$$

$$= 43,000 - 80 + 4200 = 47.2 \text{ } ^{-K}$$

48.1

SUBJECT EASTPORT HARBOR MAINE
 COMPUTATION Cell Design - Breakwater
 COMPUTED BY GTS CHECKED BY CCC DATE 2/1/61

Relative Stiffness.

$$CB = \frac{I}{14} = K = 1.0$$

$$CD = \frac{14}{25} K = .56K = 0.56$$

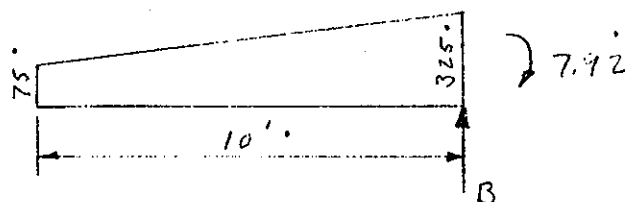
Distributing Factors

$$DF_{LB} = \frac{1.0}{1.56} = 0.64$$

$$DF_{LD} = \frac{0.56}{1.56} = 0.36$$

B		.64 C .36		D	
-7.92	+7.59	-8.73	+45.0	-47.2	
	+0.33	-23.3	-13.0		
	-11.6	+0.16	0	-6.5	
	+11.6	-0.10	-0.06		
	-0.05	+5.8	0	-0.03	
	+0.05	-3.7	-2.1		
	-1.8	+0.02		-1.0	
	+1.8	-0.01	-0.01		
-7.92	+7.92	-29.9	+29.9	-54.7	

Span AB



$$R_B = \frac{75 + 325}{2} \times 10 = 2000 \text{ ft}$$

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SUBJECT EASTPORT HARBOR MAINE

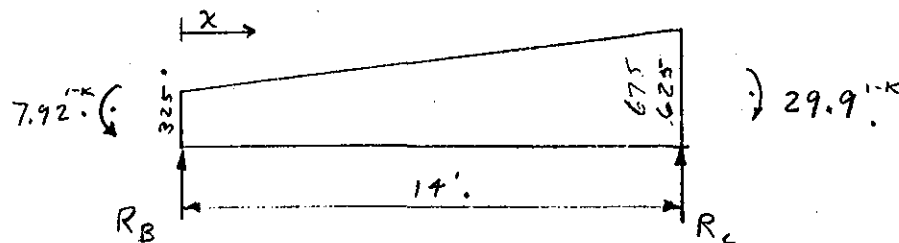
COMPUTATION Cell Design - Breakwater

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Span BC.



$$R_B = \frac{1}{2} \times 32.5 \times 14 + \frac{1}{3} \times \frac{1}{2} \times 300 \times 14 - \frac{22,000}{14}$$

$$= 2275 + 700 - 1570 = 1405 \text{ lb}$$

$$R_C = \frac{1}{2} \times 32.5 \times 14 + \frac{2}{3} \times \frac{1}{2} \times 300 \times 14 + \frac{22,000}{14}$$

$$= 2275 + 1400 + 1570 = 5245 \text{ lb}$$

PT. where $V=0$.

$$1405 - 32.5(x) - \frac{300}{14} \frac{(x)^2}{2} = 0$$

$$10.7x^2 + 32.5x = 1405$$

$$x^2 + 30.3x = 131$$

$$(x + 15.15)^2 = 376$$

$$x + 15.15 = 19.4$$

$$x = 3.8$$

$$Max + M = 1.56(3.8) - \frac{32.5(3.8)^2}{2} - \frac{0.30(3.8)^3}{14} - 7.9$$

$$5.9 - 2.3 - 0.2 = 3.4$$

-4.5 k no pos. moment.

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SUBJECT

EASTPORT HARBOR MAINE

COMPUTATION

Cell Design - Breakwater

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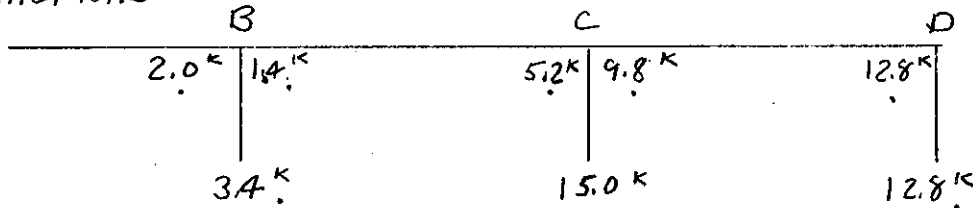
Sheet Pile Section

$$Max M = 54.7 \times 55.8 = 3034.86 \text{ K}$$

$$S_{reqd} = \frac{55.8' \times 12'}{20} = 33.5 \text{ in}^3$$

Use section equivalent to Bethlehem ZP32
 $S_{avail} = 38.3 \text{ in}^3$

TOTAL REACTIONS



TIE ROD + WATER - EL. + 2' (C)

Tie Rod

assume rod spacing = 7.5'

$$P = 15.0 \times 7.5 = 112.5 \text{ K}$$

$$A_s = \frac{112.5}{20} = 5.62 \text{ in}^2$$

use $2 \frac{3}{4}$ " ϕ rod with upset ends (5.94 in²)

Water

$$w = 15.0 \text{ K/ft}$$

$$L = 7.5'$$

$$M = 0.1 \times 15.0 \times (7.5)^2 = 84.4 \text{ K}$$

$$S_{reqd} = \frac{84.4 \times 12}{20} = 50.6 \text{ in}^3$$

$$2-12 \text{ L } 30 = 2 \times 26.9 = 53.8 \text{ in}^3$$

SUBJECT

EASTPORT HARBOR MAINE

COMPUTATION

Cell Design - Breakwater

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TIE ROD + WALE - EL + 16 (B)

Tie rod.

assume rod spacing = 15'

$$P = 3.4 \text{ kl} \times 15 = 51 \text{ kl}$$

$$A_s = \frac{51}{20} = 2.55 \text{ in}^2$$

use $1\frac{7}{8}$ " ϕ rod with upset ends.

Waler

$$w = 3.4 \text{ kl}$$

$$L = 15'$$

$$M = 0.1 \times 3.4 \times (15)^2 = 76.5 \text{ kl}$$

$$S_{reqd} = \frac{76.5 \times 12}{20} = 45.3 \text{ in}^3$$

$$2 - 12 \text{ L } 25 = 2 \times 23.9 = 47.8 \text{ in}^3$$

PILE PENETRATION DEPTH

Foundation Material:

$$\gamma_{sub} = 60 \text{ #/ft}^3$$

$$\phi = 30^\circ$$

$$K_p = \tan^2(45 + \frac{\phi}{2}) = 3.0$$

add 50% due to friction

between sub-soil + sheet pile

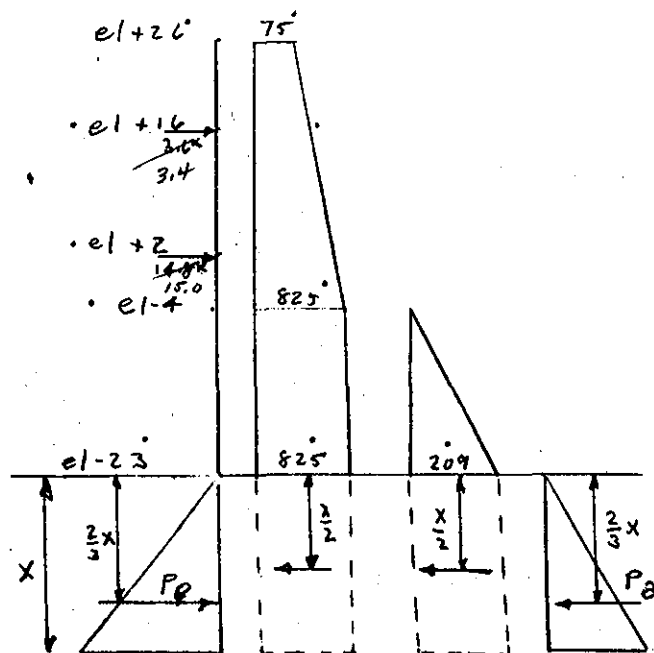
$$\text{total } K_p = 4.5$$

for factor of safety $G_s = 2$

$$\frac{K_p}{G_s} = \frac{4.5}{2} = 2.25$$

$$P_p = \frac{1}{2} (60) (2.25) x^2 = 67.5 x^2$$

$$P_a = \frac{1}{2} (60) \tan^2(45 - \frac{\phi}{2}) x^2 = 10 x^2$$



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SUBJECT EASTPORT HARBOR MAINE
 COMPUTATION Cell Design - Breakwater
 COMPUTED BY GTS CHECKED BY CCC DATE 2/1/61

Σ M about reaction @ el. +2.

$$75(30)(9) + \frac{1}{2}(750)(30)(4) + P_p(25 + \frac{2}{3}x) = 3600(14) + 825(19)(6 + 9.5) + \frac{1}{2}(209)(19)(6 + \frac{2}{3} \cdot 19) + (825 + 209)(x)(25 + \frac{x}{2}) + P_a[25 + \frac{2}{3}x]$$

$$20,300 + 45,000 + P_p[25 + \frac{2}{3}x] = 50,400 + 243,000 + 37,000 + (1034)(x)(25 + \frac{x}{2}) + P_a(25 + \frac{2}{3}x)$$

$$(P_p - P_a)[25 + \frac{2}{3}x] - 1034(x)(25 + \frac{x}{2}) = 265,100$$

$$57.5(x)^2[25 + \frac{2}{3}x] - 1034(x)(25 + \frac{x}{2}) = 265,100$$

$$x = 22' \text{ penetration (Below -23.)}$$

This depth penetration cannot be reached in this area since rock occurs between 17 and 18 feet below elevation -23. With only 17 or 18 feet of penetration a factor of $\frac{k_p}{G_s} = 3.0$ is obtained. An increase in passive resistance can be counted on due to the friction between the foundation material and the coal-tar coated sheet piling. Additional resistance will be obtained by the sheet pile section toeing into rock. Therefore a penetration of 17-18 feet down to rock appears adequate considering the added factors of friction on the sheet pile and toeing into rock.

SUBJECT EASTPORT HARBOR MAINE
COMPUTATION Landing stability
COMPUTED BY GTS CHECKED BY C.C.C. DATE 2/2/61

DESIGN DATA

Significant wave height	- 7.0 ft.	
Period	- 5.6 sec.	(T)
Deep water wave length	- 161 ft.	(L ₀)
Max. wave height = $7 \times 1.58 =$	11.1 ft.	(H)
Max. high water level	- el +23	
Bottom elev. @ structure	- el -11	
Depth of water @ structure	34 ft.	(d)
Top of structure	el +26	
Wgt of salt water	64.2 #/ft ³	

wave type.

$$\text{max. wave height} = 11.1 \text{ ft.}$$

$$11.1 \times 1.3 = 14.4 \text{ ft.}$$

$$\text{water depth} = 34 \text{ ft} > 14.4$$

∴ wave is non-breaking type.

FORCE DUE TO NON-BREAKING WAVE.

$$\frac{d}{L_0} = \frac{34}{161} = 0.2112$$

$$\frac{d}{L} = 0.2346$$

$$L = \frac{34}{0.2346} = 145$$

$$h_0 = \frac{\pi H^2}{L} \coth \frac{2\pi d}{L}$$

$$= \frac{\pi (11.1)^2}{145} \times \frac{1}{.9003}$$

$$= 3.0'$$

$$P_1 = \frac{\omega H}{\cosh \frac{2\pi d}{L}}$$

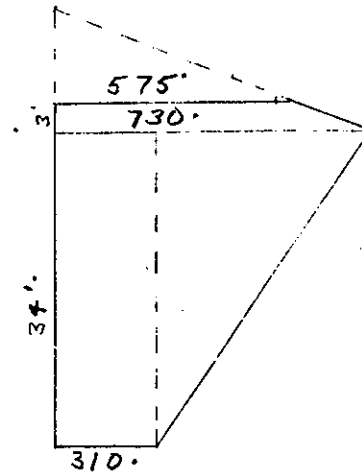
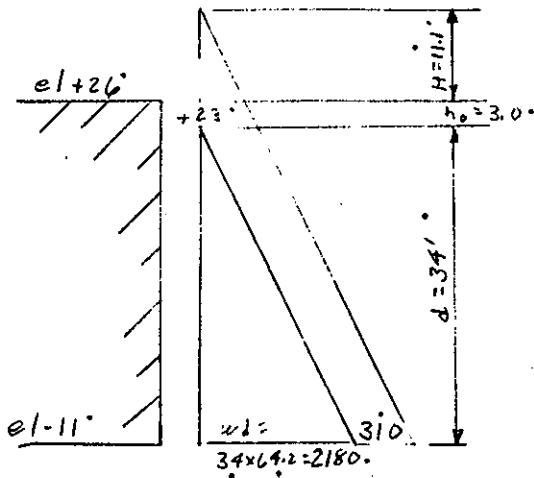
$$= \frac{64.2 (11.1)}{2.297}$$

$$= 310 \text{ #/SF}$$

SUBJECT EASTPORT HARBOR MAINE
COMPUTATION Landing Stability
COMPUTED BY GTS CHECKED BY C.C.C. DATE 2/2/61

Crest of Clapotis.

$$H + h_0 + d = 11.1 + 3.0 + 34 = 48.1'$$



WAVE LOADING.

$$\frac{2180 + 310}{48.1} (11.1) = 575'$$

$$\frac{2180 + 310}{48.1} (14.1) = 730'$$

$575' \times 3' = 1.73'$	$\times 35.5' = 61.3'$
$\frac{1}{2} \times 155' \times 3' = 0.23'$	$\times 35' = 8.1'$
$310' \times 34' = 10.54'$	$\times 17' = 179.0'$
$\frac{1}{2} \times 420' \times 34' = 7.14'$	$\times 22.7' = 162.0'$
$\Sigma H = 19.64'$	$\Sigma M = 410.4' \cdot K$

WIDTH OF CELL.

Cell Fill Material.

Submerged Rock: el-11' to el+23'
Saturated Rock: el+23' to el+26'

$$\gamma_{sub} = 50 \text{ #/ft}^3$$

$$\gamma_{sat} = 115 \text{ #/ft}^3$$

SUBJECT EASTPORT HARBOR MAINE
COMPUTATION Landing Stability
COMPUTED BY GTS CHECKED BY C.C.C. DATE 2/2/61

Total wgt of cell:

x - width of structure

$$50(x)(34) + 115(x)(3) = EV$$

$$= 2045x$$

For case of resultant falling within middle 1/3.

$$\frac{2045(x)(x)}{.6} = 410,400$$

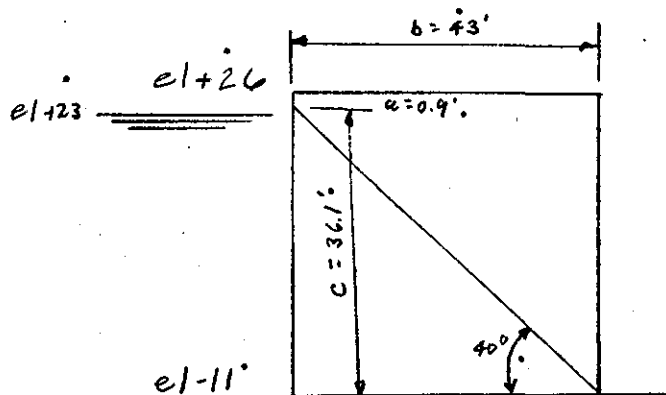
$$x^2 = 1200$$

$$x = 34.6'$$

For a filled box without a bottom

$$\frac{34.8}{0.8} = 43' \text{ width}$$

Check stability using Cumming's Method



$$\gamma = 50 \text{ pcf}$$

$$\phi = 40^\circ$$

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SUBJECT EASTPORT HARBOR MAINE
COMPUTATION Landing stability
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$$C = h \tan \phi.$$
$$= 43(.839) = 36.1'$$

$$a = 0.9'.$$

assume rock material is completely submerged.

$$M_z = \gamma \left[\frac{ac^2}{2} + \frac{c^3}{3} \right].$$
$$= 56 \left[\frac{0.9(36.1)^2}{2} + \frac{(36.1)^3}{3} \right]$$
$$= 814' \cdot \text{K}.$$

Overturning moment due to wave loading.

$$M_w = 410.4' \cdot \text{K}.$$

Factor of Safety

$$\frac{814'}{410.4'} = 1.98.$$

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COMPUTATION

Cell Design for Landing

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CELL DESIGN CONDITION FOR INTERNAL LOADING.

cell fill material (ROCK).

$$\phi = 40^\circ.$$

$$\gamma_{sat} = 115 \text{ pcf} \quad \text{el} - 4' \text{ to el} + 26'$$

$$\gamma_{sub} = 50 \text{ pcf} \quad \text{el} - 4' \text{ to el} - 11'$$

min. L.W. @ el - 4'.

assume one row of tie rods + hor walers @ el + 6'

300 pcf surcharge on top of structure.

Lateral Forces.

Sat. material

$$3' \times 25' = 75'$$

$$23' \times 25' = 575'$$

$$33' \times 25' = 825'$$

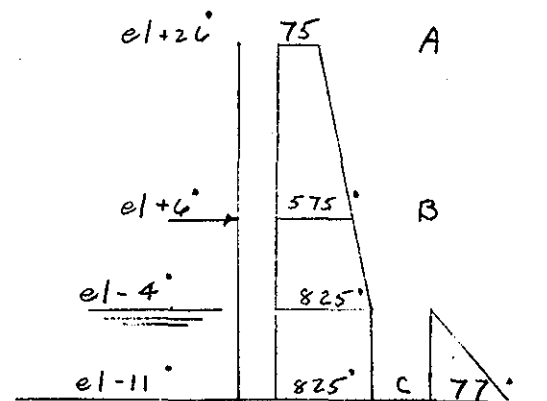
Subm. material

$$7' \times 11' = 77'$$

FEM'S.

$$\begin{aligned} \text{Cent. } M_{BH} &= \frac{75(20)^2}{2} + \frac{1}{2} \frac{(500)(20)^2}{3} \\ &= 15,000 + 33,300 = 48,300 \text{ ft-lb} \end{aligned}$$

$$\begin{aligned} FEM_{BC} &= \frac{825(17)^2}{12} - \frac{250(10)^2}{60(17)^2} \left[10(17)^2 - 10(10)(17) + 3(10)^2 \right] + \frac{77(7)^3}{60(17)^2} \left[\frac{85-30}{17} \right] \\ &= 19,900 - 2200 + 84 \\ &= 17,800 \text{ ft-lb} \end{aligned}$$



21 = 3 x 7

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SUBJECT

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Cell Design for Landing

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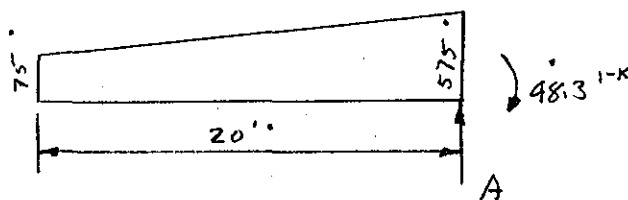
$$FEM_{CB} = \frac{825(17)^2}{12} - \frac{250(10)^3}{60(17)^2} [85-30] + \frac{77(7)^2}{60(17)^2} [10(17)^2 - 10(7)(17) + 3(7)^2]$$

$$= 19,900 - 800 + 400$$

$$= 19,500 \text{ } \#$$

A	B	C
-48.3'	+17.8'	-19.5'
	+36.5'	+15.2'
-48.3'	+48.3'	-4.3'

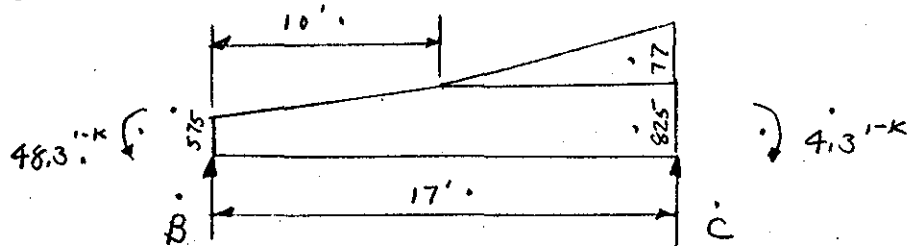
SPAN AB



$$R_A = \frac{75 + 57.5}{2} \times 20$$

$$= 6500 \text{ } \#$$

SPAN BC



SUBJECT EASTPORT HARBOR MAINE
COMPUTATION Cell Design for Landing
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$$R_R = 825 \times \frac{17}{2} - \frac{1}{2} \times 250 \times 10 \times \frac{13.7}{17} + \frac{1}{2} \times 77 \times 7 \times \frac{2.33}{17} + \frac{44,000}{17}$$

$$= 7010 - 1000 + 38 + 2600$$

$$= 8610 \text{ #}$$

$$R_L = 825 \times \frac{17}{2} - \frac{1}{2} \times 250 \times 10 \times \frac{3.3}{17} + \frac{1}{2} \times 77 \times 7 \times \frac{14.67}{17} - \frac{44,000}{17}$$

$$= 7010 - 250 + 232 - 2600$$

$$= 4400 \text{ #}$$

$$V = 0.$$

$$X = \frac{4400}{825} = 5.3' \text{ from right end.}$$

Max + M.

$$4400(5.3) - 825 \left(\frac{5.3}{2} \right)^2 - 4300$$

$$23.3 - 11.6 - 4.3 = +7.4 \text{ K}$$

Sheet Pile Section.

$$\text{Max } M = 48.3 \text{ K}$$

$$S_{\text{reqd}} = \frac{48.3 \times 12}{20} = 28.9 \text{ in}^3$$

use section equivalent to Bethlehem ZP27

$$S_{\text{avail}} = 30.2 \text{ in}^3$$

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 COMPUTATION Cell Design for Landing
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EM about el + 6.

$$75(30)(5) + P_a(17 + \frac{2}{3}x) = 825(7)(13.5) + \frac{1}{2}(77)(7)(14.7) +$$

$$(x)(825+77)(17 + \frac{x}{2}) + P_a(17 + \frac{2}{3}x)$$

$$11,250 + (P_a - P_u)(17 + \frac{2}{3}x) = 78,000 + 4000 + 902(x)(17 + \frac{x}{2})$$

$$57.5x^2(17 + \frac{2}{3}x) - 902(x)(17 + \frac{x}{2}) = 70,750$$

$$x = 17'$$

GENERAL DESIGN MEMORANDUM
FOR
CONSTRUCTION OF A BREAKWATER
AT
EASTPORT HARBOR, MAINE

EXHIBIT B
WAVE STUDY FOR BREAKWATER DESIGN

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASSACHUSETTS
MARCH 1961

EXHIBIT B

WAVE STUDY FOR BREAKWATER DESIGN

1. Purpose. - The purpose of the subject study is to determine storm wave conditions for the design of the Federal Breakwater and Public Landing.

2. Engineering and Geographical Details Considered. - Engineering and geographical details considered in this study are as follows:

- a. Fetch (length of water surface subject to wind action)
- b. Frequency and intensity of winds and their directions
- c. Heights of waves produced by winds

The following paragraphs summarize results of studies on each of the above subjects.

3. Fetch. - The maximum fetch distance extending from the breakwater site are those to the northeast as shown on plate 4 accompanying the design memorandum text. This distance is 10 miles through Head Harbour Passage. Winds from the northeast could blow over the entire water surface for this distance.

4. Winds. - Portland, Maine, located about 185 miles southwest of Eastport, is the source of wind records analyzed in this study. Wind observations are not made at Eastport. While the intensity of light winds might vary between Portland and Eastport, it is believed that high velocity and long duration winds would be nearly the same at both sites. A wind chart for Portland, extending over a 10-year period from September 1949 through September 1959, showing frequency and intensity of winds and their directions is shown on plate 4 accompanying the design memorandum text. An inspection of this wind chart and the tabulated results from which the chart was derived (not published with this memorandum) revealed that winds from the east, south, southeast and west have the highest velocity. Winds from the north through the east to the south have the longest duration with velocities ranging from 32 to 46 miles an hour. Eastport harbor is exposed to winds from the north through the northeast and to winds from the south. Although protected to the east and southeast by Campobello Island, it is exposed to limited fetches of winds from these directions.

5. Wave Heights. - The height of waves in deep water is proportional to the velocity of the wind and the distance of water surface over which these winds blow. With the wind velocity and

fetch distance known, the wave height can be determined from data presented in Beach Erosion Board Technical Report No. 4. An inspection of the harbor bottom depths approaching and at the location of the breakwater shows that "deep water" wave conditions exist.

6. The design wave characteristics are shown by the following computations. Other data on Design Wave Criteria are included in the Structural Design Section of the report.

27 Sept 49

CORPS OF ENGINEERS, U. S. ARMY

PAGE _____

SUBJECT Eastport Hbr., Maine

COMPUTATION _____

COMPUTED BY ARC.

CHECKED BY J. J. L.

DATE 28 Nov 60

Wave Height $H_{(1/3)} = 0.045 V^{1/4} \sqrt{F} \text{ miles}$

Period $T_{(1/3)} = 0.6 V^{0.4} F^{0.3}$

Maximum sustained wind speed (1 hour) 50 mph

Direction	Fetch	$H_{(1/3)}$	$T_{(1/3)}$
N	2	3.2'	3.5 Sec.
NE	10	7.1'	5.6 "
E	1	2.3'	2.8 "
SE	2	3.2'	3.5 "

Winds

10-Year record Oct. 1949 - Sept. 1959

U.S. Dept. of Commerce, Weather Bureau, Portland, Maine.

Wind Speeds over 47 mph

Direction	Duration	
E	4 hours	4 hr /
SSE	1 hour	10 yr x 365 da x 24 hr. = <u>4</u>
W	1 hour	87,650

or 1 hr in 22,000 hr wind velocity
is over 47 mph at Portland, Me.
Reasonable for Eastport, Me.

Refraction - Inspection of C&G.S. Chart 801 indicates waves
approaching down 10-mi. fetch through Head Harbour Passage
would be refracted to both sides. No possible concentration
at Breakwater site. Refraction near Cherry I., would tend to
reduce wave heights at Breakwater site.

∴ Use:

$H_{(1/3)} = 7.0 \text{ Ft.}$

$T_{(1/3)} = 5.6 \text{ Sec.}$

$L_0 = 161 \text{ Ft.}$